

Mainstreaming Ecosystem Services in National Adaptation Planning

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May 2014

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Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University 2014

Developing countries are starting the process of planning for climate change adaptation at the national level. One of the options available is ecosystem-based adaptation (EbA), which recognizes the value of ecosystem services and biodiversity for reducing people's vulnerability to climate change. The effectiveness of EbA is increasingly recognized and EbA options have been used by least-developed countries but only timidly. This research analyses the use of EbA in 18 national adaptation plans produced by a representative sample of developing countries across the globe. It found that all plans proposed at least some EbA measures, mostly in the coastal sector, followed by the water sector, the agriculture sector, and finally the urban sector. The extent to which EbA is used in these different sectors appears to follow the state of the literature. EbA is recognized in these plans for providing many ecosystem services linked to reduced vulnerability to climate change. Moving forward, evidence on effectiveness should be developed for the agriculture, water, urban, and to a lesser extent coastal sector. Financing of EbA should be increased for implementation, and co-benefits emphasizing the cross-cutting nature of EbA should be incorporated in the development of national plans.

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1. Introduction

Greenhouse gases (GHG) emissions have been rising dramatically for many decades because of anthropogenic activities, leading to climate change. Climate change is leading to changes in socio-economic and ecological systems. More droughts, more floods, spread of tropical illnesses, food insecurity, water insecurity, sea-level rise, extreme weather events, and loss of biodiversity will result if no global policy reform is undertaken (Barker, 2007). In addition to mitigation efforts, consisting of reducing emissions of GHG, countries need to adapt because the current level of GHG leads to some warming already. National adaptation planning policies are being developed in large a number of countries. In the United Nations Framework Convention on Climate Change (UNFCCC), financial provisions are being channeled specifically to target adaptation to climate change, for example through the Adaptation Fund.

The vulnerability of a system to climate change depends on its sensitivity and exposure to climate change, and its adaptive capacity (Smit & Wandel, 2006). Developing countries tend to be the most vulnerable to tackle climate change because of their higher dependence on natural resources and their limited financial, technical, and institutional capacity (OECD, 2009). Current investments in low income and middle income countries to reduce the impacts of climate change are insufficient, leading to increased vulnerability. Natural systems are all affected by climate change and their resilience has a limit (Heller & Zavaleta, 2009). Therefore, both socio-economic and ecological systems are at risk, and particularly so in developing countries (Adger et al., 2005).

Ecosystem-based adaptation (EbA) to climate change is defined as “the adaptation policies and measures that take into account the role of ecosystem services (ES) in reducing the vulnerability of society to climate change, in a multi-sectoral and multiscale approach” (Vignola, Locatelli, Martinez, & Imbach, 2009). This topic has been gaining momentum in the literature (W. R. Turner, Oppenheimer, & Wilcove, 2009). In parallel, international climate policy negotiations are attempting to take an ecosystem services approach into account for the mitigation of climate change, in the form of reducing emissions from deforestation and forest degradation (REDD+). The benefits of ecosystem services are not limited to the mitigation of climate change via carbon sequestration. Mangroves, for example, have the capacity to protect populations from storm surges, which are likely to be increasingly damaging because of climate change (Das & Vincent, 2009). In addition, mangroves also help protect biodiversity, fisheries, and improve the resilience of ecological and social systems.

The choice to employ EbA is often a choice among EbA and “soft” or “hard” adaptation measures. An example of EbA measures, in contrast with soft measures (e.g. capacity building, information,

knowledge) and hard measures (e.g. technology, capital goods), is presented in table 1. The potential of ecosystem-based adaptation activities needs more investigation if the goal of using ecosystem services to efficiently and effectively adapt to climate change is to be attained. Protected areas provide ecosystem services that increase socio-ecological resilience and help communities to mitigate as well as adapt to climate change (R. K. Turner, Burgess, Hadley, Coombes, & Jackson, 2007). Moreover, some evidence suggest that this ecosystem based adaptation is cost-effective (Jones, Hole, & Zavaleta, 2012) (Doswald et al., 2014), which would make it attractive in the design of national adaptation planning where finance is limited.

| Sector | Country | Objective | Soft measure | Hard measure | EbA measure |
|-------------|-------------|--|--|---|---|
| Coastal | Pakistan | Coastal Protection | Develop communities' evacuation plans for vulnerable coastal and other areas against cyclones and sea storms | Construct cyclone shelters | Plantation and regeneration of mangroves, coastal palm and other trees suitable to the area |
| Agriculture | Zambia | Decrease Vulnerability to climatic changes | Provision of accessible climate information to farmers and pastoralists | Breeding techniques | Agroforestry: potential to abate 4.2 Mt CO ₂ e by 2030, while offering climate resilience benefits of improved food security, soil quality, improved soil water retention, reduced erosion, and perennials that are better able to withstand climatic changes. |
| Water | Philippines | Improve Water Quantity | Risk transfer mechanisms | Implement water harvesting technologies | Identify and prioritize rehabilitation of degraded watersheds |

Table 1: Three examples of EbA measures, in contrast with soft and hard measures, found in documents analyzed in this study

Developing countries are particularly vulnerable to the effects of climate change, and livelihoods tend to rely more heavily on natural systems than in developed countries (UNDP, 2010). Because of this, EbA, using natural systems to decrease vulnerability of people to climate change, has been suggested as particularly suitable for investigation in developing countries (Vignola et al., 2009). Current development assistance may increase or decrease vulnerability to climate change, depending on the degree to which risk assessment with respect to climate change is taken into account (McGray, 2007). Mainstreaming adaptation into development is therefore essential to ensure better resilience and better adaptation of developing countries in the future. To reach this goal, National Adaptation Programs of Action (NAPAs) were developed in 2002 in the UNFCCC 7th conference of the party in Marrakech (UNFCCC, 2002). NAPAs are designed to provide a platform for least developed countries (LDCs) to prioritize their adaptation action. The rationale behind the program is that the LDCs that are most vulnerable to climate change also have the least adaptive capacity. Other developing countries that are not classified among the least vulnerable, are still very vulnerable, and currently have large natural areas that provide ecosystem

services. These natural areas may however be at risk because of rapid economic growth in recent decades. Since the international community has taken stock of this issue, international mechanisms to support the protection of ecosystem services, such as REDD and Payments for ecosystem services (PES), are being developed, but national policies may not reflect this trend.

Recent evidence suggest that NAPAs take into consideration ecosystem services, though not very extensively (Pramova et al., 2012). In their study, Pramova et al. found that 30 out of 44 NAPAs identified ecosystem services as important, mainly for sustaining livelihood (70% of the NAPAs). To a lesser extent, ecosystem services were identified to provide protection from disaster (23%) and to benefit human health (6%). Cultural benefits were identified in 2% of the NAPAs. Most of the ecosystems providing services identified in the NAPAs were forests and woodlands, followed by coastal and marine, and species diversity. Regarding the priority projects presented in the NAPAs, 69% do not contain ecosystem activities, 8% contain ecosystem activities for the environment (classic conservation), 6% contain ecosystem activities for the social well-being, and 16% contain ecosystem activities for social adaptation.

In addition to the NAPAs, national adaptation plans (NAPs) also offer an avenue for ecosystem-based adaptation. These plans are undertaken by national governments voluntarily, sometimes with the help of international organizations, to design a pathway for adaptation at the national level. These plans are multi-sectorial, and have longer timeframes than NAPAs. NAPs are still in their early stage of implementation, which makes them more open to modification. A number of countries are developing their own programs and NAPs. Some member states of the OECD have published a national adaptation plan, some have published an adaptation strategy, while some are simply taking action without a formal strategy (Mullan, 2013). Despite this progress on adaptation, National Adaptation Plans also face challenges. Too often, a very top-down approach is used during the planning process with too few stakeholders involved. Adaptive capacity is still lacking because of information shortcomings, securing appropriate finance to develop and implement the plans, as well as measuring the effectiveness of the plans (Mullan, 2013). More research is needed to formulate effective policy for adaptation and there is a need for assessing initiatives taken by different countries to evaluate best practices.

Furthermore, there are many challenges specific to the EbA approach (A. Colls, N. Ash, 2009). There is currently a lack of financing for EbA projects. EbA projects can lead to land use conflicts because of the lack of recognition of communities' rights by governments, the displacement of people for reforestation projects (see Feagin 2010 for a discussion of this issue in the coastal sector), and knowledge gaps on the effectiveness of EbA exists. Particularly, the financing of EbA can result in distributional inequalities of both socio-economic and environmental amenities (Kronenberg & Hubacek, 2013). More importantly, the science of ecosystem services and particularly ecosystem-based adaptation is in a

nascent stage. Technical reports have been recently released by relevant institutions which are directly useful for the formulation of national planning documents (UNFCCC, 2013) but the extent to which it has been incorporated in the climate change adaptation policy making process is not clear. EbA will have to be used in synergy with other soft and hard adaptation approaches to be effective. In addition, there needs to be more research on the costs and benefits of EbA. Finally, social and ecological resilience of EbA projects are limited and may not be effective after a certain intensity or degree of climate change ((W. R. Turner et al., 2010; Ostberg, Lucht, Schaphoff, & Gerten, 2013).

Recognizing the challenges of national adaptation planning and of EbA as a sound adaptation tool, the objective of this master project is to synthesize the extent to which EbA is currently being prioritized in national adaptation planning documents as well as synthesize the state of ecosystem services science relevant to climate change adaptation. Building on these two analyses, the second objective is to formulate policy recommendations in order to better include EbA in national adaptation plans.

This analysis is timely since recent technical papers on EbA have been published under the Nairobi work programme on impacts, vulnerability and adaptation to climate change in order to help decision-makers in the design of national adaptation policy (UNFCCC, 2013). The first round of national adaptation plans has been published in numerous developing countries in the past few years. It is therefore important to have this analysis now to inform policy-makers for the review of their NAP and to prepare for following NAPs (for example, Tonga's "Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management" is for the 2010 to 2015 period (Tonga 2010).

The focus on national planning documents is also relevant because of the multi-sectorial approach of national adaptation plans compared to NAPAs, which the lack thereof was identified as a barrier to the development of EbA (Pramova et al. 2012). National planning is also an important scale of analysis because interactions between mitigation and adaptation can be assessed (Swart & Raes, 2007). Here, it will be possible to report the use of ecosystem services for adaptation mitigation simultaneously.

This research will result in management and policy recommendations on EbA for policy makers. This project will attempt to fill the gap in the emerging topic of ecosystem-based adaptation, the opportunity of using ecosystem services as a tool for adaptation to climate change. My goal is to understand if national governments are considering EbA in their national adaptation plans and other national adaptation policies and to what extent. If there is a lag between NAPs and the state of the science on ecosystem-services, the goal of this study will be to formulate policy recommendations to bridge this gap.

The specific research questions that this Master's Project will attempt to answer are:

1. How is the emerging science related to ecosystem services being considered in national adaptation planning in developing countries?
2. What are the recommendations and existing gaps in the ecosystem service literature related to adaptation to climate change?
3. Based on the findings from 1 and 2, to what extent do missed opportunities exist at the national planning level?

Based on the current state of the literature, the following hypotheses were formulated:

H1: Because UNFCCC and donors like the Global Environment Facility (GEF) are promoting EbA, EbA will be more developed in national planning documents where they are involved.

H2: Because EbA is site specific, there will be variability from country to country usage of EbA

H3: Because EbA is cost-effective, countries with higher budget constraint will use more EbA

H3b: Appraisal method matters. Because of co-benefits and difficult economic valuation of services, EbA will be used more when multi-criteria analysis (MCA) is used rather than benefit-cost analysis (BCA).

H4: Because EbA is an emerging concept, most recent plans will have more EbA

H5: When EbA is used, 1st sector mentioned will be forestry, then coastal sector

H6: It will be difficult to distinguish between EbA activities and adaptation of ecosystems activities proposed in the NAPs

However, these hypotheses are only here to guide the development of this project. Because of the early stage of research on ecosystem-based adaptation (Doswald et al., 2014), this project is deductive in nature whereas hypothesis testing is more relevant for inductive research.

2. Methods

I conducted a literature review on the state of the science in the field of ecosystem-based adaptation to climate change. Particularly, I assessed the current work on scientific and economic appraisal of the potential gains from using this approach, integrated with other “soft” and “hard” adaptation options.

Secondly, I assessed the integration of ecosystem-based adaptation into national adaptation plans. This analysis was guided by the findings from Pramova et al. (2012), as well as from Doswald et al. (2014). Pramova et al. extracted information on regulating and provisioning (purposefully omitting supporting) ecosystem services mentioned in the NAPA background sections and the NAPA project profiles, which allowed for the classification of EbA based on the type of EbA project, the sector, the type of service, the service provided, and the proportion of EbA with respect to other options. Because NAPAs are completed under particular requirements, they differ from NAPs. Contrary for NAPAs developed by the least developed countries (LDCs), the UNFCCC does not mandate any state to develop other national adaptation planning documents. For this reason, a representative sample of countries that have developed these planning documents was selected based on several criteria, described in the following section. In addition, the total number of adaptation measures in each plan was not recorded for time constraints, so that the proportion of EbA with respect to other options was not determined.

2.1 Selection of Countries

To be able to generalize my findings to most developing countries, a sample of twenty countries was selected based on the following criteria: the existence of national adaptation planning documents; representative across a range of income groups; a balance between LDCs and non-LDCs; representative across a range of sub-regions; a balance between beneficiaries and non-beneficiaries of major international climate change adaptation funds (including the Adaptation Fund (AF) and the Pilot Program for Climate Resilience (PPCR)), and direct acknowledgement of international support in the national adaptation plan.

The list of countries selected for this study and their attributes can be found in Table 1. These countries have formulated policy responses to climate change in the form of policies, strategies, or plans. These will be commonly addressed as national adaptation plans (NAPs).

Two documents, Marshall Islands' "National Climate Change Policy Framework", and Ethiopia's "Climate Resilient Green Economy Strategy", do not lay out specific adaptation options. It was therefore not possible to analyze them in detail and they were thus removed from this analysis. It is also important to notice that Brazil's "National Plan on Climate Change" was included in this study even though only the executive summary and not the complete plan was analyzed.

| Country | Region | Income Group | LDC | International support | Adaptation Policy | Year |
|------------------|-------------------------|--------------|-----|-----------------------|--|------|
| Bangladesh | South and Central Asia | LIC | Yes | Yes | Climate Change Strategy and Action Plan | 2009 |
| Brazil | South America | UMIC | No | No | National Plan on Climate Change | 2007 |
| China | Far East Asia | UMIC | No | No | National Climate Change Programme | 2007 |
| Cook Islands | Caribbean | UMIC | No | Yes | Joint National Action Plan for Disaster Risk Management & Climate Change Adaptation 2011-2015 | 2011 |
| Ethiopia | Africa, South of Sahara | LIC | Yes | No | Climate Resilient Green Economy Strategy | 2011 |
| Ghana | Africa, South of Sahara | LMIC | No | No | National Climate Change Adaptation Strategy | 2012 |
| India | South and Central Asia | LMIC | No | No | National Action Plan on Climate Change | 2008 |
| Indonesia | Far East Asia | LMIC | No | No | Climate Change Sectoral Roadmap | 2009 |
| Kenya | Africa, South of Sahara | LIC | No | No | National Climate Change Action Plan 2013-2017 | 2012 |
| Laos | Far East Asia | LMIC | Yes | No | Lao People's Democratic Republic's Strategy on Climate Change | 2010 |
| Marshall Islands | Oceania | UMIC | No | No | National Climate Change Policy Framework | 2011 |
| Morocco | Africa, North of Sahara | LMIC | No | No | National Plan to fight Global Warming | 2009 |
| Namibia | Africa, South of Sahara | UMIC | No | No | National Policy on Climate Change for Namibia | 2011 |
| Nigeria | Africa, South of Sahara | LMIC | No | No | National Adaptation Strategy And Plan of Action | 2011 |
| Pakistan | South and Central Asia | LMIC | No | Yes | National Climate Change Policy | 2012 |
| Philippines | Far East Asia | LMIC | No | No | National Climate Change Action Plan 2011-2028 | 2011 |
| South Africa | Africa, South of Sahara | UMIC | No | No | National Climate Change Response White Paper | 2011 |
| Tuvalu | Oceania | UMIC | Yes | No | Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management 2010-2015 | 2010 |
| Tonga | Oceania | UMIC | No | Yes | National Strategic Action Plan for Climate Change and Disaster Risk Management 2012-2016 | 2012 |
| Zambia | Africa, South of Sahara | LMIC | Yes | Yes | National Climate Change Response Strategy | 2010 |

Table 2: Key characteristics of the 20 selected developing countries and their national adaptation plan. In grey, the two plans that were removed from the analysis for lack of detail available

2.2 Selection of Sectors

I decided to focus on five sectors: coastal, agriculture, water, urban, and environment sectors. These sectors have the highest potential for the use of EbA, and they are some of the most common sectors found in national adaptation planning documents. All the planning documents consider the water sector. Seventeen out of eighteen considered the agriculture sector, 16 the environment, 15 the urban, and 13 the coastal sector. Notably, Zambia is the only landlocked country in this study and therefore does not include a coastal sector in its plan. Other sectors not considered in this study include health and education, among others. When measures to adapt to extreme events on the coast were reported in the disaster sectors, they were included in this study. In essence, all EbA measures were recorded since they were always categorized in one of these sectors.

2.3 Categorization of Measures

Pramova et al. (2012) categorized actions when they analyzed NAPAs. Three categories of projects were developed for projects with ecosystem activities. If the project did not mention people, it was categorized as ecosystem activities for the environment. If people were targeted then it was categorized as ecosystem activities for the social well-being. Finally, if the project mentioned reducing people's vulnerability to climate, then it was categorized as ecosystem activities for social adaptation.

This categorization method was not appropriate for my analysis because the documents list adaptation measures instead of on-the-ground projects. Therefore, two categories were made for measures related to the environment: "*measures for the environment*", and "*EbA-relevant measures*". The second category uses the definition in Doswald et al (2014), which includes direct EbA measures, as well as measures that generally improve adaptive capacity or decrease vulnerability of the economy. Measures referring to integrated management were included in this category, because integrated management refers to both human and natural systems. Measures linked to mitigation of climate change using the environment, such as REDD or carbon sequestration goals, are also included in this EbA-relevant category. The first category, *measures for the environment*, contains measures specifically directed at conserving, managing, or restoring the environment for its own sake.

The divide between these two categories is not always clear, as suggested by hypothesis H6. For example, the Philippines state that "Climate change can also affect the goods and services provided by ecosystems. Degraded ecosystems will be less resilient to climate change and extreme events. Conversely, healthy and stable ecosystems can lessen the impacts of climate change." Therefore, they express the idea that ecosystems will be affected by climate change and so need to be protected, but also that this protection will be beneficial for the economy as well. Therefore, when the context did not mention ecosystem services or benefits of the activities for socio-economic systems (as opposed to natural systems) these activities were identified as *measures for the environment*.

2.4 Socio-Economic Variables

Income group was reported using the World Bank Country and Lending Groups database (World Bank, 2014). International support was based on member countries of the Pilot Program on Climate Resilience (PPCR), member countries of the Adaptation Fund (AF), and countries that acknowledged support from

international organizations in the NAPs, including UNDP, UNEP, GEF, WB, SPREP, CI, WWF, and Greenpeace.

3. Results

3.1 Description of the National Adaptation Plans

Only two documents, Pakistan's "National Climate Change Policy" and the Philippines "National Climate Change Action Plan 2011-2028" explicitly mention the term "ecosystem-based adaptation" (Pakistan, 2012; Philippines, 2011). However, all of the 18 NAPs analyzed here selected EbA-related measures but did not identify them as such. This inconsistency between the use of the term ecosystem-based adaptation and the proposal of *EbA-related measures* has also been identified in other studies (Munroe et al., 2012).

There is a wide variation across NAPs in the number of proposed measures related to the environment (figure 1), defined here as any measure with an environmental component, including both ecosystem-based adaptation and measures to protect environmental health. Pakistan is the country that proposes the largest number of measures related to the environment (28). Ghana has the lowest number of these measures (2). Considering *EbA-relevant measures* only, Pakistan also has the largest number (12), and Ghana and Lao PDR have the lowest number (1).

In terms of sectors, 16 countries planned adaptation measures in the environment sector, which are all *measures for the environment*, i.e. directed towards the protection, conservation, and adaptation of the environment to climate change. Five NAPs also identify EbA-relevant measures in the environment sector. For example, Nigeria plans to "increase the extent and diversity of forest cover in order to address increased aridity caused by higher temperature and greater rainfall variability" (Nigeria, 2011). All the plans with a coastal sector propose adaptation measures related to the environment in that sector. This therefore builds evidence towards the hypothesis stating that the coastal sector is the most popular to use EbA. Twelve out of the 20 countries that plan adaptation measures in the water sector propose the use of EbA or the conservation and adaptation of ecosystems. For the agriculture sector, this number falls to eleven out of 19, and only 6 out of 17 countries identify EbA or protection of ecosystems for the urban sector.

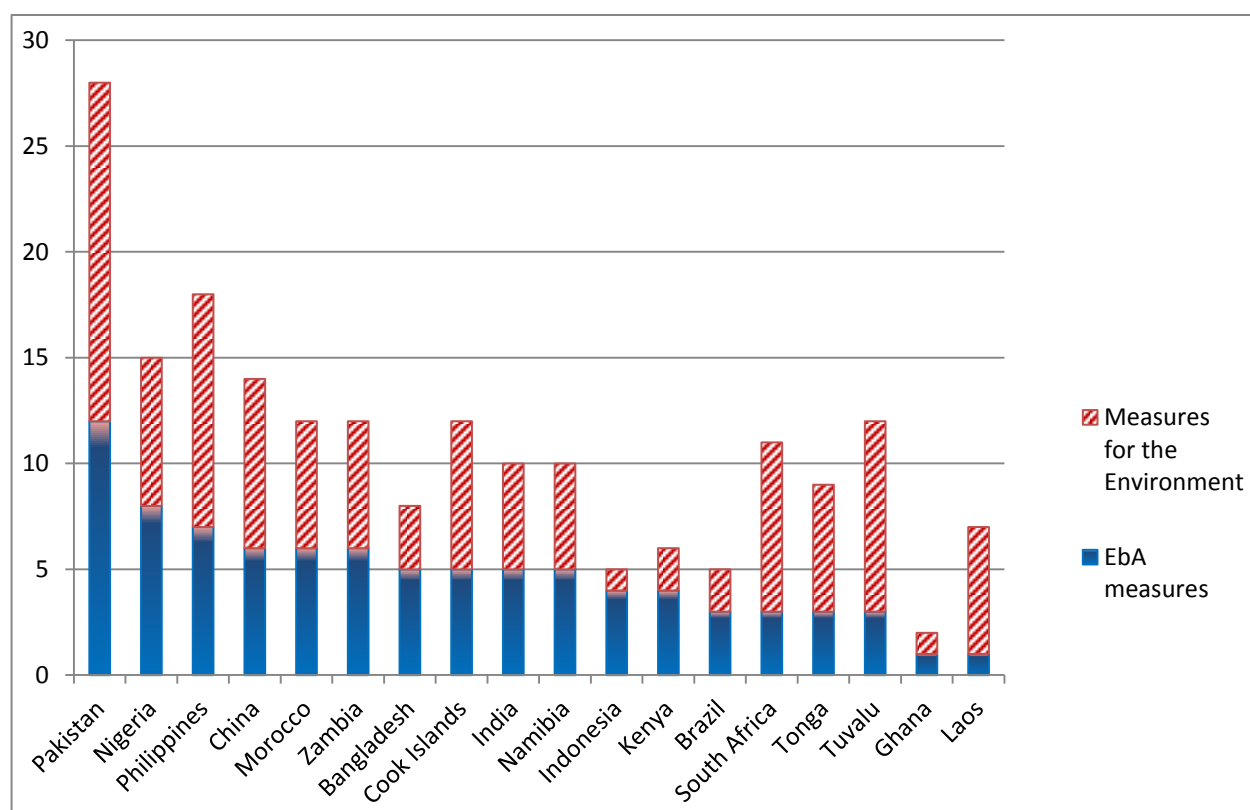


Figure 1: Total number of adaptation measures related to the environment

3.1.1 EbA-Relevant Measures

As described above, all NAPs proposed adaptation measures related to the environment. For the remainder of this study, I will only focus on *EbA-relevant measures*. Measures and activities only targeting the protection and adaptation of ecosystems for ecosystem health (*measures for the environment*) as the sole objective will not be furthered analyzed. In this section, I will first report the objectives of EbA-relevant measures proposed in NAPs. Second, I will report the strategies used as ecosystem-based adaptation measures. In both of these sections, I will explore trends in aggregate across NAPs. Third, I will characterize socio-economic trends that influence the number of *EbA-relevant measures* in NAPs. Fourth, I will describe the synergies between adaptation and mitigation for ecosystem services. I will conclude this section by comparing the proposed EbA-relevant measures with other soft and hard adaptation measures proposed in NAPs.

3.1.1.1 Objectives of EbA-Relevant Measures

Ecosystem-based adaptation can serve many objectives as an option to decrease the vulnerability of countries to climate change and increase people’s resilience to climate change. They can be used in most sectors of the economy to directly reduce the impacts of future climate change, including damages linked to changes in temperature, precipitation, and extreme events. The 18 national adaptation plans analyzed here capture this variety of objectives that EbA can fulfill.

Coastal protection is the primary objective of EbA-relevant measures found in these documents. A quarter of all *EbA-relevant measures* (26%) have this objective (Figure 2). For the protection of the coastline, *EbA-relevant measures* are used for the protection of livelihoods and infrastructure against extreme events and floods, linked to climate change and sea-level rise. Some measures also mention using EbA for dissipating wave energy, and reducing coastal erosion.

The second largest objective for proposed EbA-relevant measures is water management, with 16% of total measures targeting this objective (Figure 2). Watershed protection for water supply is mentioned as an important goal, followed by run-off, erosion, and flood prevention.

Fourteen percent of EbA-relevant measures were proposed in the agriculture sector. These measures, mostly in the form of agro-forestry, aim at increasing the productivity of crop and livestock production, through soil stabilization, nutrient cycling, decrease the impacts of increased temperature and water variability, diversification of agriculture systems, and resistant species. Preventing desertification is an objective identified in 3% of EbA-relevant measures, and is probably linked to agriculture and land-use.

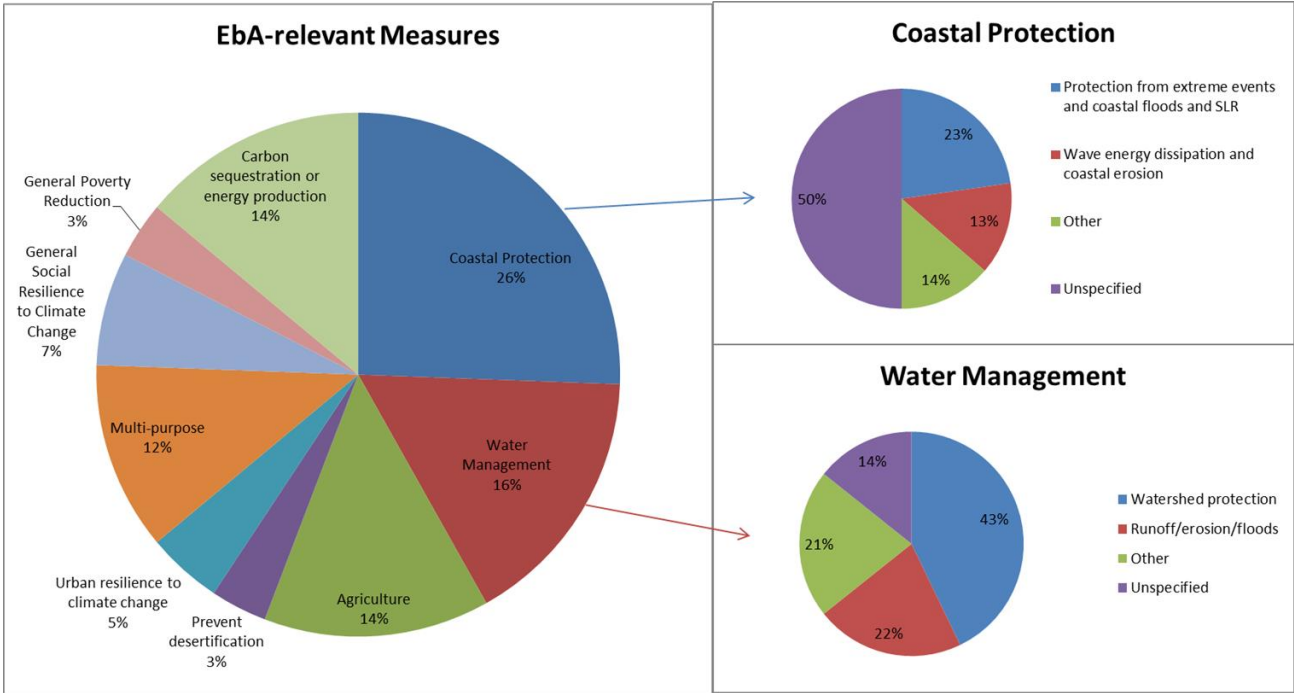


Figure 2: Objectives of the EbA-relevant measures found in the 18 national adaptation plans

Twelve percent of all *EbA-relevant measures* proposed have multiple objectives: adaptation plus mitigation objectives, adaptation in several sectors simultaneously, or several objectives within a single sector. Co-benefits and provision of many ecosystem services is an important benefit of EbA. Poverty reduction is recognized as the objective of 3% of all EbA. Also carbon sequestration and energy production linked to livelihoods. The fulfillment of multiple objectives, the reduction of poverty, and the mitigation benefits are some of the traits of ecosystem services that have been emphasized in recent work (Millennium Ecosystem Assessment, 2005).

3.1.1.2 Strategies of EbA-relevant Measures

This sub-section will describe which strategies are employed for using ecosystems to reach the objectives described previously and to reach the overarching objective of climate adaptation.

The majority of *EbA-relevant measures* use forest ecosystems, including mangroves (Figure 3). Most of the measures involve reforestation or afforestation of forests. Restoration of forests development of artificial forests as green infrastructure is also popular. These four types of forests management represent 36% of all strategies of *EbA-relevant measures* found in the NAPs. Agro-forestry is mentioned in 8% of *EbA-relevant measures*, and forest conservation (including the use and research of conservation tools such as REDD) represents 12% of *EbA-relevant measures*. Overall, 56% of all *EbA-relevant measures* suggest using forest ecosystems to decrease the vulnerability and increase the resilience of the country.

The conservation, restoration, and management of ecosystems other than forests characterize 20% of *EbA-relevant measures* (Figure 3). These measures are found in a wide variety of ecosystems, including from most frequent to least frequent: coastal and marine, wetland, river and lake, grassland, urban, and mountain ecosystems. In addition, generic biodiversity conservation as a mean to achieve adaptation to climate change is mentioned in 3% of *EbA-relevant measures*.

Other adaptation strategies include management practices involving ecosystems. Integrated Coastal Zone Management represents 8% of all *EbA-relevant measures* and general land-use management practices represent 3% of all *EbA-relevant measures*. Finally, 10% of all *EbA-relevant measures* only mention the general use of ecosystem services for adaptation.

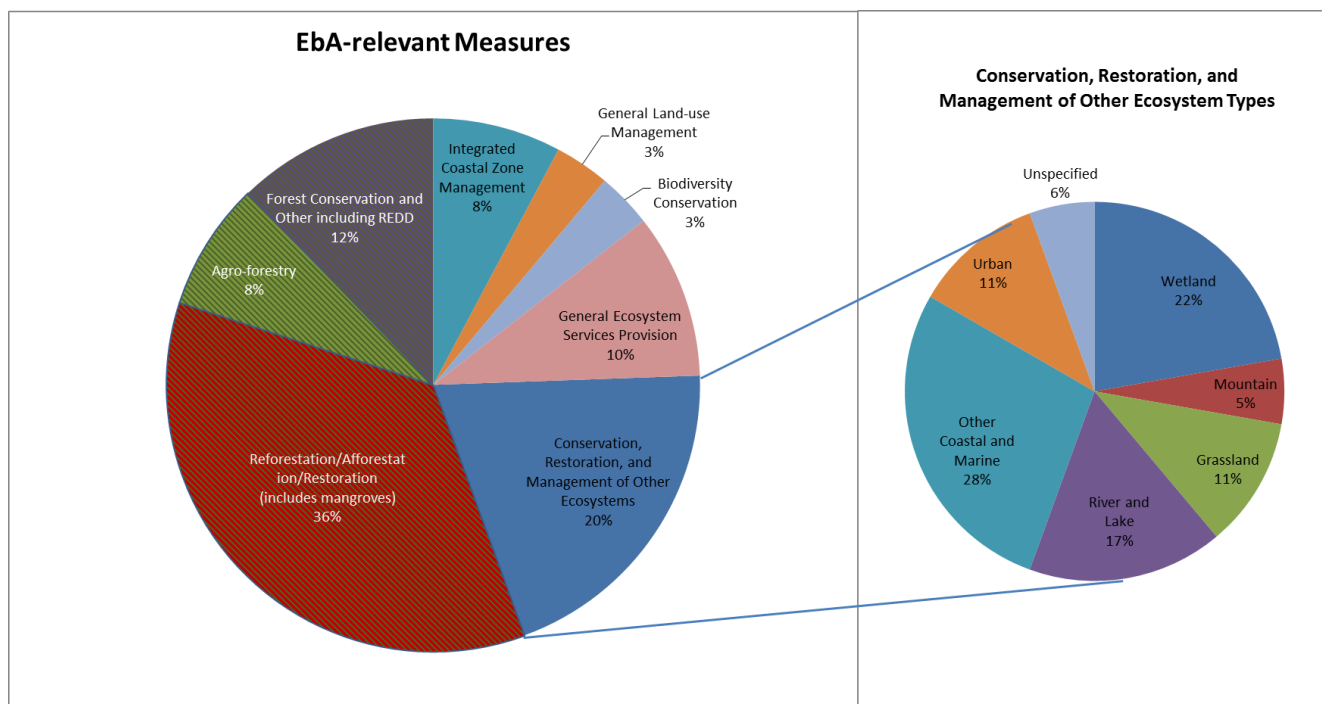


Figure 3: Strategies of EbA-relevant measures found in the 18 national adaptation plans. The pattern fill with the white font represents forest ecosystem type

3.1.1.3 Geographic and Socio-Economic Drivers of EbA

National adaptation plans analyzed here were published between 2007 and 2012. No clear trend in the evolution of the number of *EbA-relevant measures* in each plan was found over the years (Figure 4).

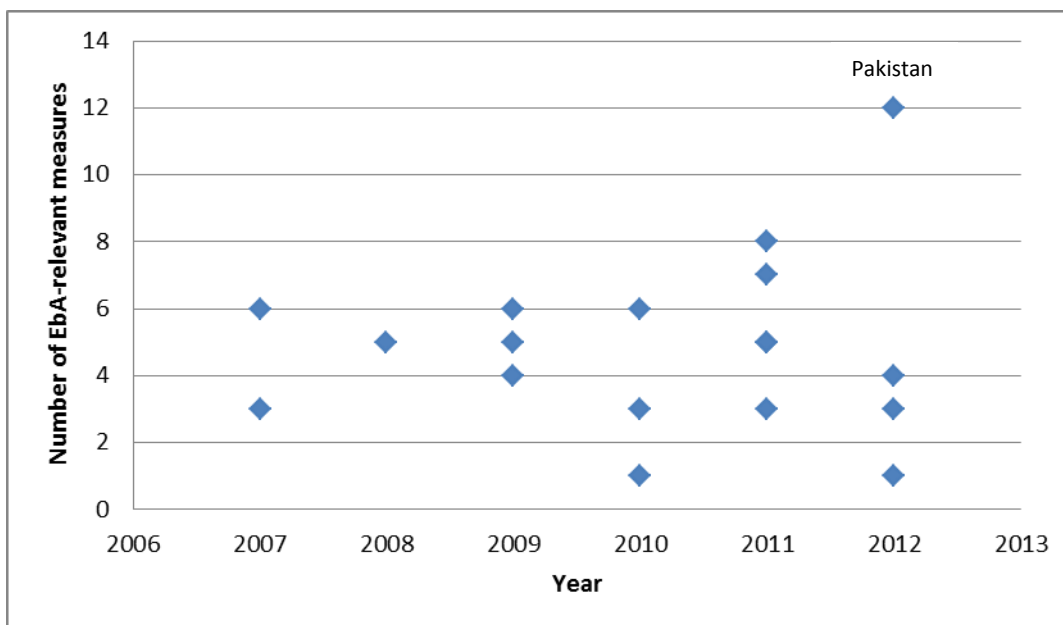


Figure 4: Evolution of the Number of EbA-relevant Adaptation Measures over the Years. Each dot represents a NAP

There seems to be regional differences in the average number of EbA-related measure proposed (Table 2). However, the sample size in each region is too small to draw conclusions. There are also differences in the average number of EbA-related measure proposed with respect to income groups. The mean number of EbA-relevant measures for the low income developing countries (including LIC and LMIC World Bank income group) is 6.5 measures per document (n=11). The mean for the higher income developing countries (UMIC World Bank income group) is 4.0 measures per document (n=7).

| Region | Mean # EBA-relevant Measure per Document | n |
|-------------------------|--|---|
| Africa, North of Sahara | 6 | 1 |
| Africa, South of Sahara | 4.7 | 6 |
| Caribbean+Oceania | 3.7 | 3 |
| Far East Asia | 4.5 | 4 |
| South America | 3 | 1 |
| South and Central Asia | 7.3 | 3 |

Table 2: Mean Number of EbA-relevant Measures per Document for each Sub-region.

3.1.2 Synergies between Adaptation and Mitigation

One of the advantages of using EbA instead of other soft and hard adaptation options is the mitigation benefits generated by the carbon sequestered in ecosystems. Mangroves provide a very large carbon sink worldwide (Bouillon et al., 2008), while being one of the most threatened ecosystems (Murray, 2012).

Out of the 18 documents analyzed here, 13 include plans for both adaptation and mitigation and five exclusively focus on adaptation. Fourteen documents list ecosystem activities for mitigation or for both mitigation and adaptation purposes. Despite Nigeria's "National Adaptation Strategy and Plan of Action" exclusively focusing on adaptation, it acknowledges the mitigation value of ecosystems, thus explaining why only thirteen documents target mitigation but fourteen mention mitigation and adaptation benefits of ecosystem services (Nigeria 2011). The number of EbA-relevant measures for mitigation and adaptation range from one to three per document. Six measures explicitly link mitigation and adaptation of EbA in various ecosystems, including forests, wetlands, and agroforestry. Six documents mention the use of REDD and REDD+ for mitigation and/or forest restoration purposes. In addition, three documents include measures for utilizing payments for ecosystem services, carbon offsets, and other forms of financing to promote EbA-relevant activities. Most of the ecosystem activities for carbon mitigation mention reducing deforestation, reforestation, and afforestation. Two measures focus on energy fuel from forests and forests products.

The countries included in this study, and particularly the ones belonging to the LDC category, are very limited financially. Therefore, the inclusion of REDD+ as a financing tool for the implementation of EbA measures is an innovative approach, given that REDD+ originally targets mitigation and not adaptation. This also emphasizes the multiple benefits of ecosystem services in terms of adaptation and mitigation, and provides an argument for their cost-effectiveness.

Provision of finance is also a moral issue because of the growing ecological debt that developed countries are imposing on developing countries (Srinivasan et al., 2008). Estimates of the cost of adaptation range from 9-41 US\$ billion per annum to 86-109 US\$ billion per annum worldwide (Parry et al., 2009). In addition, UNFCCC 2007 estimates do not include the cost of adaptation for ecosystems because of lack of data (Parks, 2007). In parallel to these sources of funding, new market mechanisms are being developed to conserve and encourage the use of ecosystem services, such as REDD+, payments for ecosystem services (PES), and integrated conservation and development projects (ICDP). However, there is no consensus on the effectiveness of these instruments (Miteva, Pattanayak, & Ferraro, 2012). These

new instruments deserve to be further investigated because they could leverage new incentives towards the use of ecosystems for adaptation and mitigation (Wertz-Kanounnikoff, 2011).

3.1.3 Soft and Hard Adaptation Measures

In most cases, other soft and hard adaptation measures are also identified in addition to *EbA-relevant measures* (Figure 5). Soft and hard adaptation options were mentioned more frequently than *EbA-relevant measures*. All of the NAPs that considered the water, the agriculture, and the coastal sectors included soft adaptation measures. Ninety-three percent of the documents included soft adaptation measures for the urban sector, such as the integration of climate change issues into development planning strategies. All of the agriculture sectors documents included hard adaptation measures, such as irrigation and water harvesting technologies. Ninety five percent of the NAPs that considered the water sector included hard adaptation measures, such as the construction of dams. In the coastal sector, 85% of the NAPs selected hard adaptation measures, such as the construction of cyclone shelters. Finally, 80% included hard adaptation measures in the urban sector, such as redesigning the drainage system.

Hard and soft adaptation measures are more consistently proposed than *EbA-relevant measures* in all sectors (Figure 5). This suggests that hard and soft measures are more widely accepted as appropriate. On the other hand, some documents selected *EbA-relevant measures* without soft and/or hard adaptation measures in the same sector. South Africa's "National Climate Change Response White Paper" does not select any hard adaptation measure in its coastal sector, but formulated the following *EbA-relevant* measure: "Protect and rehabilitate natural systems that act as important coastal defenses, such as mangrove swamps, offshore reefs and coastal dunes." (South Africa, 2011).

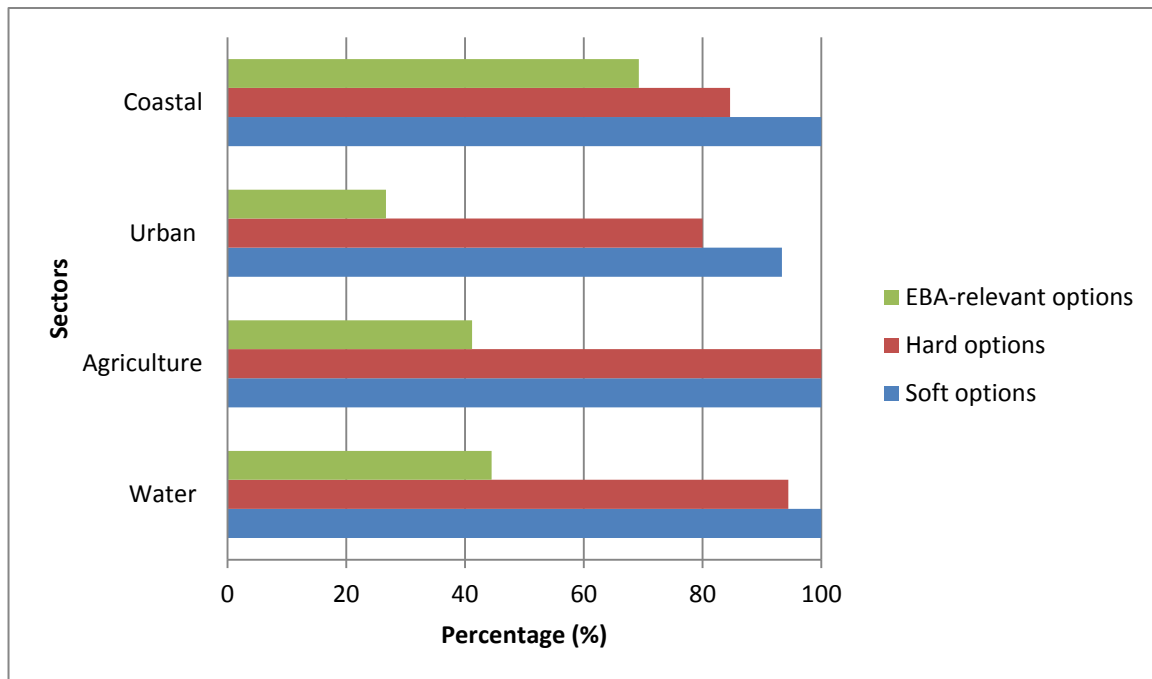


Figure 5: Percentage of NAPs proposing at least one soft, hard, and/or ebA-relevant measure by sector.

3.2 Literature Review on Ecosystem-Based Adaptation: two case studies

Results show that *EbA-relevant measures* have been selected in many adaptation plans. However, EbA is a novel area of research and the effectiveness of such measures is uncertain. A recent review of the evidence found that the majority of EbA projects yields positive results (Doswald et al., 2014). To understand how much the *EbA-relevant measures* selected in these plans are in accord with the state of the science, I will compare the science and the proposed measures for two sectors: the coastal sector, where the most *EbA-relevant measures* are found in this analysis, and the urban sector, which contains the least number of *EbA-relevant measures*. First, the state of the science, gaps in the literature, and recommendations were formulated for the coastal and urban sectors. Secondly, these two reviews were compared to the measures found in the adaptation documents.

3.2.1 The Coastal Sector

The coastal sector is composed of the socio-ecological systems located on the coast of countries. The coastal sector is also one of the sectors that are expected to be the most impacted by climate change

(Barker, 2007) due to sea-level rise, ocean acidification, increased storm surge, flooding, and extreme weather events such as cyclones. Climate change will adversely affect the livelihood of coastal communities as well as infrastructure from villages to ports and megacities. Adaptation measures in this sector are mostly targeted to decrease the vulnerability of natural features such as coral reefs and mangroves, as well as human settlements, such as cities to the impact of climate change. It is often an important sector for the economy with major cities and ports and a high percentage of the population being located on the coastlines around the world.

The boundaries around the coastal sector delineated here are arbitrary. In the Cook Islands' "Joint National Action Plan for Disaster Risk Management & Climate Change Adaptation 2011-2015", measures to adapt infrastructure are presented in their coastal sector (Cook Islands, 2011). In the Philippines "National Climate Change Action Plan 2011-2028", coastal adaptation is presented in the urban sector (Philippines, 2011). Besides, the literature often focuses on specific ecosystems to further the understanding of ecosystem services and ecosystem-based adaptation instead of having a whole sector as the scope of study. I chose the latter approach, focusing on sectors, to reflect the sectorial approach taken in national adaptation plans. This creates challenges to categorize cross-cutting adaptation measures. Several plans do not have a specific coastal sector but include adaptation measures to reduce vulnerability of other sectors to the same climate change impacts, such as sea-level rise. In addition, the urban sector will be treated as a separate sector. Therefore, only adaptation measures that mitigate the impacts of climate change on coastal cities will be considered here. Other impacts on urban settings will be considered later.

3.2.1.1 State of the science

This review will provide an overview of the role that intact coastal ecosystems can play at mitigating the adverse impacts of climate change. These adverse impacts on the coastal sectors are sea-level rise and increased erosion, storm surge, extreme events, and ocean acidification. Coastal ecosystems reviewed here include mangrove forests, marshes, reefs, seagrasses, and dunes.

Evidence suggests that intact coastal ecosystems mitigate the effects of sea-level rise, extreme events and storm surge (Gedan et al., 2010; Pramova et al., 2012). This evidence is largely based on the fact that these systems reduce vulnerability (defined as exposure, sensitivity, and adaptive capacity) of coastal populations and infrastructure to current and historical conditions. While the processes that lead intact coastal ecosystems to mitigate the effects of climate change have been questioned recently (R a

Feagin et al., 2009) because it was argued that the geomorphology of the site is the most important determinant of coastal protection, other research suggests that the presence of coastal vegetation itself is responsible for the protection against recurring, slow-intensity events that will be exacerbated by sea-level rise (Gedan et al., 2010).

In fact, several processes are at play in understanding the ecosystem services provided by intact coastal vegetation. Coastal protection from vegetation, particularly mangroves and marshes, is not uniform and two separate interactions with climate change have to be considered. First, coastal vegetation can reduce the effects of sea-level rise by mitigating flooding, erosion, and wave strength. Evidence is strong that coastal ecosystems effectively protect coastlines against these long-term and low energy impacts of sea-level rise. Direct mechanisms involve the physical presence of the vegetation, both above ground and below ground, which decreases water velocity and decreases erosion (Gedan et al., 2010). Other indirect mechanisms such as accumulation of organic matter through the decay of roots, and facilitation of sediment deposition through water stagnation where vegetation is located, as well as other mechanisms help protect coastal soils from erosion. The protective capacity of intact coastal ecosystems is less evident for tsunamis and storm surges.

Storm surges and extreme weather events such as tropical storms are also expected to increase with climate change, and these impacts may be mitigated by coastal ecosystems. However less is understood about the capacity of coastal ecosystems to effectively protect against these rapid high energy events such as storm surge (Feagin et al., 2010; Das & Vincent, 2009). Evidence shows that this function is context-specific (Alongi, 2008). Major spatial and temporal nonlinearities exist (Barbier et al., 2008; Koch et al., 2009). Also, the mitigating capacity depends on the features of the vegetation, the geology and topography, the storm conditions, and the interactions with other coastal ecosystems. Nevertheless, instances where wetlands have dampened storm surges have been reported, from 4.4cm to 15.8cm reduction in surge height per km of wetland (Krauss et al., 2009). The meta-analysis conducted by Gedan et al. (2010) shows that even relatively narrow area of intact wetlands offer protection against storm surge. A more recent modeling study found that mangrove forests are effective at reducing impacts of storm surge but this effectiveness is tightly linked to forest width and to the category of hurricane that generates the storm surge (Zhang et al., 2012).

Even though most studies have looked at the role of mangrove forests and marshes, other vegetation types may also contribute to protect the coastline (Barbier et al., 2011). Seagrasses and oyster beds dissipate wave energy. These vegetation types can be found in juxtaposition and reinforce the reduction of coastal erosion (Swann, 2008). Native vegetation can also be restored and managed in synergy with the construction of hard infrastructure to control erosion, even though more research needs

to be undertaken to understand the interactions between the hard and soft systems (Ondiviela et al. 2013).

In addition to their role in adaptation, the preservation of coastal ecosystems provides co-benefits (Pramova et al. 2012; Barbier et al. 2011). They sequester carbon, thus participating in the crucial mitigation effort to reduce GHGs (Duarte et al., 2013; Siikamäki, Sanchirico, & Jardine, 2012). They provide other regulating services such as water quality, and provisioning services such as habitat and nurseries for fish, wood, and fuel (Alongi, 2002). These services increase wealth of coastal communities and diversify their source of income, thus increasing their resilience to climate change.

However, coastal ecosystems will be adversely affected by climate change, which may reduce their capability to provide services (Craft et al., 2009). The distribution of habitat such as seagrasses and mangroves will shift with climate change (Duarte et al., 2013). It appears that mangroves follow changes in sea-level depending on rates of sea-level change and vegetation induced accretion. Some evidence suggests that mangroves may fail to migrate at high rates of sea-level rise (M. Kirwan & Temmerman, 2009), even though they are currently keeping up with the rate of sea-level rise at the global scale (Alongi, 2008). In addition, low-lying areas such as most of the small island countries in the Pacific are particularly vulnerable because the topography does not allow coastal ecosystems to migrate if significant sea-level rise occur. It seems that resilience of coastal wetlands to climate change is better than forecasted, thanks to submergence-accretion feedbacks, and plant productivity-submergence feedbacks (Gedan et al., 2010).

Furthermore, some coastal ecosystems are more vulnerable than others. Because different plant species have different tolerance to climatic changes and sea-level rise, species composition of mangroves may change in the future in relation with sea-level rise. Carbon in salt marshes can only accumulate until a certain threshold of sea-level rise, after which vegetation dies (Mudd, Howell, & Morris, 2009). On the other hand, salt marshes can adapt thanks to the accretion rates, making them resilient to sea-level rise (M. L. Kirwan & Mudd, 2012). In addition, current pressures due to human development are compromising the resilience of coastal ecosystems to climate change (Orth et al., 2006). These local characteristics and local pressures on coastal ecosystems make conclusions about their potential role for climate adaptation difficult at the global scale (Ondiviela et al., 2013).

3.2.1.2 Gaps

Many gaps remain in the scientific literature in order to make the restoration, protection, and management of coastal ecosystems a useful tool for policy-makers in the development of adaptation plans. The cost-effectiveness of wetland preservation, even though asserted in many academic articles,

has rarely been explicitly valued, nor has it been compared with other options (R. K. Turner et al., 2007). Valuation studies have showed promising results for the use of coastal ecosystems for coastal protection (Costanza et al., 2013; Das and Vincent, 2009) but these studies are neither comprehensive nor holistic in their approach. Even though EbA should be used synergistically with other adaptation options and not replace them, costs and benefits have to be estimated precisely when decision-makers operate under budget constraints.

In addition, a comprehensive analysis on the limits to resilience of ecosystems to climate change, and the possible reduction in ecosystem services due to climate change has to be undertaken (Ondiviela et al., 2013). Because the characteristics of coastal ecosystems are specific to an area, analyses of benefits and resilience have to be conducted at the local scale. Relying on the current estimates of services could lead to maladaptation if the vulnerability of these ecosystems and the potential loss of their function due to climate change is not understood.

While ecological engineering is an emerging field (Borsje et al., 2011) new research needs to formulate innovative approaches and synergies between ecosystems to provide optimal services and coastal protection (Swann 2008; Gedan et al., 2010). Ecosystem services such as coastal protection are now relatively well understood for mangroves and marshes. Nevertheless, a lack of understanding remains regarding other coastal ecosystems such as reefs and seagrasses (Barbier et al., 2011; Ondiviela et al., 2013). In addition, careful analysis has to be undertaken for a better understanding of the introduction of exotic species as an ecosystem-based adaptation tool, because of their potential adverse effects to native biodiversity and to communities (Feagin et al., 2010).

Now that EbA is starting to be implemented, new challenges arise. Mangrove planting projects have created conflicts with communities (Faegin et al., 2010). These projects could also be mismanaged, giving a false sense of security if they do not sufficiently reduce exposure of communities to extreme weather events. Land tenure is also an issue, if communities can be displaced, or customary rights are not respected or acknowledged by the government. These issues have to be addressed to ensure that EbA projects in the coastal sector do not undermine the adaptive capacity of the most vulnerable communities.

3.2.1.3 Recommendations

Overall, the protection, restoration and management of intact coastal ecosystems can be a useful adaptation tool. The structure, function, and services they provide are context specific, and need to work hand in hand with community-based adaptation, policy development and with regular grey infrastructure.

Therefore, challenges emerge when designing national adaptation plans using EbA: cross-cutting approaches, synergies with other approaches, community appropriation, context-specific successes (Faegin et al. 2010).

EbA should be used hand-in-hand with other soft and hard adaptation measures (Jones, Hole, and Zavaleta 2012; Pramova et al. 2012). These different measures are not mutually exclusive. Soft options such as early warning systems should be developed first because they provide great benefits at low cost (Das and Vincent 2009; Hallegatte, 2009). EbA can help reduce the cost of maintenance of hard infrastructure which is often undervalued or is hard to account for because of uncertainty (Pramova et al., 2012; Hallegatte, 2009; Jones, et al 2012). In addition, EbA can reduce some of the adverse effects of hard infrastructure, such as erosion. Therefore, great synergy potential exists.

In addition to their role in protecting coastlines, there are co-benefits in terms of provisioning services, regulating services, carbon sequestration, and biodiversity. These have to be accounted for by decision-makers but are difficult to value quantitatively in current economic analysis. To reach this goal, multi-criteria analysis (MCA) may help support decisions because it can integrate qualitative outcomes in addition to quantitative ones. In addition, natural capital valuation methods are being developed around the World. Because these services could potentially provide livelihood to the poor and the most vulnerable members of society, they are often in line with national objectives of poverty reduction in developing countries that works hand-in-hand with national adaptation plans. National adaptation planning is one of the appropriate venues to respond to the missed opportunity identified in Pramova et al. regarding targeting the social groups and economic sectors relying on ecosystems for their livelihood (Pramova et al. 2012; W.N. Adger, 2000)). The cost-effectiveness of EbA makes it attractive as it is, and Blue Carbon, in the form of a REDD+ financial mechanism, could be used to conserve coastal ecosystems of mitigation purposes, further reducing the costs of EbA (Murray, 2012). More than cost-effectiveness, EbA is a powerful tool as it is reducing both “hazard” and “vulnerability” in a pressure and release model framework. This model links physical hazards that adaptation is aiming at reducing exposure to, and vulnerability of populations due to social and political factors (W. Neil Adger, 2006).

Seven broad conclusions can be made from this assessment of the state of the science. Coastal ecosystems can provide protection from the adverse impacts of climate change, but the extent of this service is not well understood and may be limited by local factors. Mangrove forests and salt-marshes are the best studied coastal vegetation types, but other types such as seagrasses can provide similar services. In addition, synergies between different vegetation types could increase service provision over time (Harris, Hobbs, Higgs, & Aronson, 2006). Co-benefits derived from management and conservation of these ecosystems is high and should be considered when evaluating adaptation options. Service provision may be hampered because of future climate change and other anthropogenic pressures. The relative capacity

of these systems to provide viable adaptation option varies locally. Development and implementation of EbA projects can be challenging and could lead to conflicts, increased vulnerability, or degradation of ecosystems, in addition to the risk of introducing exotic species.

3.1.2.4 Assessment of the EbA-relevant Measures Identified in the Coastal Sector

The objectives that are the most commonly used across NAPs in the coastal sector consider the use of coastal ecosystems to reduce the effect of waves and sea-level rise on coastal erosion, followed by the use of coastal ecosystems to protect the coast against extreme events such as tsunamis and cyclones. This stronger emphasis on the role that coastal ecosystems can play on slow changes versus extreme changes is consistent with the current state of the science that has not reached a consensus on the extent to which coastal vegetation effectively protects communities against extreme events.

Most of the EbA-relevant measures use mangroves and other trees (9), which is consistent with the fact that mangroves are the most studied coastal vegetation with respect to their potential for climate adaptation. All other coastal vegetation are found at least once across the NAPs, including coastal wetlands, coral reefs, oyster reefs, sand dunes, estuaries, and kelp beds.

Only two measures proposed in the NAPs explicitly mention the use of native species, and one EbA-relevant measure mentions non-native plant species. While the use of non-native species is not a concern when the strategies involve restoration of ecosystems, it could be when plantations are considered, such as Bangladesh's coastal greenbelt projects, involving mangrove planting along nearly 9,000km of coastline. Here, the literature is clear on the caveats of using non-native species, and this is the topic with the widest gap between the literature and the national adaptation plans.

None of the measures mention the climate change mitigation benefits of coastal ecosystems, even though it is recognized in the scientific literature as having a very high potential. Only two plans consider the use of multiple coastal vegetation types, which is a new area of research. However, the integration of coastal ecosystems into the broader economic context of the coastal sector and other forms of adaptation is widely recognized since six plans are proposing to implement integrated coastal zone management. Nonetheless, only two plans explicitly mention synergies between EbA-relevant measures and hard infrastructure to protect the coast against climate change. For example, China proposes to "adopt measures of combining slope protection with shore protection, combining engineering measures with biological measures". Again, this is a new topic in the scientific literature, it was therefore expected that only a small fractions of NAPs would acknowledge it.

3.2.2 The Urban Sector

Urban areas are characterized by human influence. Urbanization is growing, especially in developing countries. Urban areas will be impacted by climate change in many ways (heat stress, water stress, floods, and extreme events). Urban ecology is a new field of research, from which developing concepts of socio-ecological systems, urban biogeochemistry, and ecological footprints of cities have emerged (Grimm et al., 2014). The ecological footprint of urban areas is much larger than the cities themselves, but for the scope of this study I will only focus on adaptation to urban areas themselves. In addition, the productive land and ecosystems from which urban areas draw resources are treated in other sectors: coastal, agriculture, water, and the environment.

EbA in the urban sector, sometime defined as urban green infrastructure (Gaffin et al., 2012) or bio-infrastructure, brings new solutions to urban sustainability and climate change adaptation.

3.2.2.1 State of the science

Urban Green Infrastructure (UGI) is a recent endeavor, and the full extent of its effectiveness and potential as an adaptation option is still limited. However, recent research argues that this EbA could be effective, yield co-benefits, and be less costly than grey infrastructure (Gaffin et al., 2012).

Urban vegetated areas reduce surface temperature and mitigate the heat island effect characteristic of urban areas. In Manchester, UK, surface temperatures are expected to increase by 4.3°C in town centers by 2080 under a high emissions scenario, but a 10% increase in green cover would be enough to almost entirely compensate this temperature increase (Gill, 1998). Using remote sensing, Tiangco et al. (2008) also found a negative relationship between temperature and vegetation cover. A review paper on observational evidence found that parks were 1°C on average cooler than surrounding areas (Bowler et al., 2010). It also found that this effect increased with park size and that the cooling effect extended beyond the park boundaries. Some studies reported in the same paper have also reported a cooling effect for single trees and green roofs (Oke, 1997), but evidence of this effect is less clear than for parks and forests (Bowler et al., 2010). Trees also provide evapotranspiration which has a cooling effect (Pataki et al., 2011).

In addition to parks and street trees, green roofs are the best studied use of nature to provide ecosystem services linked to climate change adaptation in cities (Lundholm & Peck, 2008). Green roofs can be used to adapt to change in precipitation regimes. In cities that are expected to experience more

precipitation, green roofs act as runoff detention basins. It also decreases the flow of water entering the existing urban water infrastructure. Green spaces allow water infiltration into the soil and reduce water flow through evapotranspiration (Bolund & Hunhammar, 1999). Urban green infrastructure thus provides cooling, water storage and reduces runoff.

Besides providing services to dampen gradual effects of climate change, green spaces may provide regulating services against extreme events like heat waves and floods that are expected to increase with climate change (Depietri, Renaud, & Kallis, 2011). Trees in urban areas can mitigate spikes in air pollution associated with heat waves (Jim & Chen, 2009; Nowak et al., 2000). This reduction in air pollution depends on pollutants in the air, and the type and density of trees, which is overall well understood (Depietri, Renaud, & Kallis, 2011).

However, trade-offs exist because the maintenance of vegetation requires water resources which may be negatively affected by climate change. Increased evapotranspiration by the vegetation also decreases the water level (McCarthy, Pataki, & Jenerette, 2011). Nonetheless, climate change mitigation benefits also exist since dampening of the urban heat island effect with increase vegetation cover also decreases cooling needs, and thus energy consumption and production of GHG (McPherson 1994). In addition, native species requiring less water use could be used to reduce water consumption.

The effectiveness of green infrastructure to provide the regulating services described above may be reduced in stressful conditions such as heat waves, air pollution, and water quality and quantity issues and extreme rain events. The services provided are also limited. In the case of protection from flooding, urban forests are not capable of stopping large-scale floods (Eisenbies et al., 2007).

Inversely to the idea that increase in green infrastructure can be a viable adaptation strategy, the loss of ecosystems to urbanization is reducing the buffering of hazards that these ecosystems provide (Alberti, 2005). Urbanization leads to the heat island effect and changes in water flow that could increase vulnerability to floods. It also fragments ecosystems and degrades the ecosystem services they provide. Therefore, a first strategy would be to reduce urbanization pressure and to protect the surrounding natural ecosystems.

3.2.2.2 Gaps

Apart from green roofs and traditional landscaping, new urban green infrastructure is emerging, such as rain garden and green walls. However, cost benefit evaluations, effectiveness, and implementation on large scales still need to be assessed (Gaffin et al., 2012).

There are no best practices available yet on the type, in addition to the structure, and the size of green infrastructure to use for adaptation to climate change in developing countries (Bowler et al., 2010).

Most of the studies are in the temperate zone, and more studies are needed in tropical zones and islands, where many developing countries studied here are located and where different processes may be at play (Jonsson, 2004).

3.2.2.3 Recommendations

Based on the review of the state of the science, it is difficult to provide specific recommendations for using EbA in the urban sector. Green infrastructure should be considered in developing adaptation measures for this sector because of its effects on reducing temperature, flooding, public health outbreaks due to sewer overflows, and improving air quality. However, studies have to be conducted at the city scale to select the optimal type, distribution, and size of green infrastructure for effective adaptation to climate change. As for other EbA activities, co-benefits in terms of carbon sequestration and other ecosystem services such as recreation are not negligible and should be included in the decision-making.

3.2.2.4 Assessment of the EbA-relevant Measures Identified in the Urban Sector

The number of EbA-relevant measures identified in the urban sector in the NAPs is very low (Figure 5). Only four measures refer explicitly to the urban sector. These measures include the revitalization of green spaces and shade (Nigeria, 2011), the construction of vegetative barriers to protect human settlements from sandstorms (Pakistan, 2012), an ecosystem-based management for eco-towns (Philippines, 2011), and the establishment of eco-towns in protected areas (Philippines, 2011).

The shade service provided by urban vegetation is extensively discussed in the literature; it is therefore not surprising to find it here. However, other services provided by urban vegetation, such as water management and co-benefits, including pollution prevention and GHG mitigation, have not been identified in the NAPs.

H1: Because UNFCCC and donors like the Global Environment Facility (GEF) are promoting EbA, EbA will be more developed in national planning documents where they are involved.

There does not seem to be a difference between countries that do and that do not have support from international organizations.

H2: Because EbA is site-specific, there will be variability from country-to-country usage of EbA

There is variability in the number and in the strategies of EbA used across countries. However, there are also some EbA measures commonly found (objectives, types of ecosystems, and strategies) across the NAPs. For example, restoring and conserving mangroves for protecting the coast against climate change is proposed in seven out of the 18 NAPs.

H3: Because EbA is cost-effective, countries with higher budget constraint will use more EbA

There seems to be evidence that support this assertion, since LIC and LMIC combined has a higher number of EbA per NAP on average (6.5, n=11) than UMIC (4.0, n=7).

H3b: Appraisal method matters. Because of co-benefits and difficult economic valuation of services, EbA will be used more when multi-criteria analysis (MCA) is used rather than benefit-cost analysis (BCA).

This was not possible to assess because the decision-making process was not explicitly described in many of these NAPs.

H4: Because EbA is an emerging concept, most recent plans will have more EbA

I found no evidence to support this hypothesis since there is no trend over time.

H5: When EbA is used, 1st sector mentioned will be forestry, then coastal sector

The coastal sector has the most EbA, followed by the water, the agriculture, and finally the urban sector.

H6: There will not be a clear distinction between EbA and adaptation of ecosystems

It was indeed difficult to distinguish EbA from measures for the environment.

4. Discussion

4.2 Limitations

The documents analyzed here are just plans and the actual implementation of these measures cannot be assessed. Some plans, like China's "National Climate Change Programme" is very ambitious and lists many measures, but is it realistic (China, 2007)? Furthermore, several of the country plans presented here are LDCs, so that there may be spill-over effects from NAPAs into other national adaptation planning documents (maybe options have already been identified in NAPAs and restated here).

It was sometimes difficult to establish the goals of measures involving ecosystems. Furthermore, since these are high-level plans, the measures are not all on-the-ground projects. The scale difference makes it difficult to know how synergies, interactions, and problems with some of the EbA-relevant measures will arise when implemented locally. When a plan refers to afforestation as a mean of adaptation and then afforestation as a mean of mitigation, it is not possible to know if the same afforestation project will target both objectives or not.

Some documents have many measures, some have less. The proportion of EbA-relevant measures to the total number of measures included in the documents was not quantified. Countries that list a large number of measures may also list higher number of EbA-relevant measures, which may skew the results. This relationship could be explored thanks to the reporting of every measure in every plan analyzed here.

Technical documents to help developing countries prepare national planning documents have just been released, and it is possible that this will positively impact the number and percentage of EbA-relevant measures in future NAPs (UNFCCC, 2013). Since the latest documents analyzed here are from 2012, this may explain why no trend over time was found. It would be interesting to see if our findings hold true for plans developed after 2013.

For future development, there should be an opportunity after the completion of this project to compare the development of adaptation policies to climate change in developed and developing countries. This study should be able to bring a better understanding on the different challenges and opportunities that these groups of countries face regarding to the use of ecosystem services for a successful adaptation to climate change.

4.1 Discussion of Results

This study shows the broad mention of ecosystems in the NAPs is common. The use of EbA is developed, especially in the coastal sector. However, some important benefits of the EbA strategy are not acknowledged. EbA is often qualified as win-win-win adaptation, where it also has co-benefits in terms of

mitigation and poverty reduction (The Royal Society 2008). This win-win-win is however not acknowledged in many of the plans analyzed here. Links between adaptation and mitigation based on ecosystems are made in some NAPs. One plan also discuss the need to expand research on using REDD for forest ecosystems that also increase resilience to climate change (Zambia 2010). Link to poverty reduction is also weak, as only two EbA-relevant measures directly target poverty reduction, even though poverty and gender issues are targeted by ten national adaptation plans.

It seems that the plans follow the state of the science. Only based on case studies for two sectors of the economy, the coastal and the urban sectors, I found that there are many more EbA-relevant measures in the coastal sector than in the urban sector. This finding is coherent with the fact that the science of EbA in the coastal sector is at a more advanced and operational stage than for the urban sector. Even though research on ecosystem services in urban settings has been active since the 1990s', urban ecosystem services directly related to climate change is more recent (Grimm et al., 2014). However, the spatial delimitation of sectors of the economy could undermine this statement. Indeed, successful adaptation of the urban sector will depend on its surrounding environment, including for example where its water comes from. These exogenous factors are artificially separated in NAPs due to the sectorial break down of activities. Some plans acknowledge this weakness and propose cross-sector measures. For example, the Philippines "National Climate Change Action Plan 2011-2028" combine the urban and the coastal sector (Philippines, 2011). Therefore, some EbA-relevant measures were characterized as having a water management or coastal protection objective, when they overall participate in the adaptation of urban areas.

Pramova et al. found that 50% of the NAPAs contained ecosystem services, while only 22% contained EbA measures. Comparatively, this is lower than the 100% of NAPs proposing EbA measures found here. Pramova et al. identified, in the 5 LDC countries that are also analyzed in this study, only one (for Bangladesh, Ethiopia, Laos, and Zambia) or two (for Tuvalu) projects with ecosystem activities for social well-being and social adaptation to climate. In the NAPs subsequently developed and analyzed here, this range is from 3 to 12 measures with ecosystem activities. There could be several factors explaining this difference. First, NAPs are long term comprehensive plans that propose a large number of measures for several sectors, whereas NAPAs are small programs that identify only a few priority projects. Second, the NAPs have been developed more recently than NAPAs, so that they could have benefited from a stronger science on EbA and better international support, even though this explanation is contradicted by our findings which do not show a trend over time in the frequency of EbA proposed measures. Here, I found no EbA measure related to the provision of cultural services. However, cultural values associated with natural systems have been stated in some of the plans. For example, China

identified the need to “principle of harmony between human and nature in water resource management” (China 2007).

5. Conclusion

This paper described the use of ecosystem-based adaptation, or EbA-related measures, in the national planning documents of 18 developing countries. Even though all documents selected EbA-related measures, the range in the number of measures proposed by different countries is wide and cannot be explained by geographic or socio-economic factors. The EbA-relevant measures selected are overall in accordance with the state of the science on ecosystem services, which is still in its nascent stage for the most part. There are less EbA-relevant measures selected than other soft and hard adaptation options for all sectors in NAPs. However, it is hard to prescribe the relative importance of these three forms of adaptation. Ultimately, they have to be undertaken in synergies with each other for a successful adaptation and sustainability. High-level plans such as the ones analyzed here are important, but adaptation measures will be implemented at the local scale, where exogenous factors will determine the success of EbA or not. Therefore, monitoring and evaluation of Ecosystem-based Adaptation will be crucial to learn from best practices and implement truly resilient adaptation strategies.

This work could inform decision-makers, national governments and international development organizations for the planning of future NAPs. Much can be learned from the assessment of how other countries are planning to adapt. For instance, 6 plans identified REDD as a vehicle to finance EbA. Other countries may want to look into this measure as well.

There is a need to keep working on effectiveness of EbA, especially for sectors other than coastal. Also need to work on synergies between different ecosystem for most effective EbA, and synergies between EbA and other adaptation measures. Now that there is preliminary evidence on effectiveness of EbA, and that NAPs contain EbA measures, on top of the facts that guidelines have been developed at the project level (GEF, 2012), it is vital to make these guidelines work at the national level, and identify financing tracks for adaptation projects., There is also a need to develop decision-making tools that allow for valuation of ecosystem services and co-benefits that characterize EbA.

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